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HUMAN RESOURCES

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MAINTENANCE SUPPORT RESOURCE FORECASTING MODELS

By

Sharon R. Nichols
Stacey A. Fenner

LOGISTICS AND TECHNICAL TRAINING DIVISION
Logistics Research Branch
Wright-Patterson Air Force Base, Ohio 45433

June 1982

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AFHRL has worked with and developed three maintenance support resource forecasting models. They are the Logistics Composite Model (LCOM), Reliability and Maintainability Model (R&M), and the Expected Values Model (EVM). The objective of this study is to analyze these three models in terms of (a) how they relate to each other, (b) the minimal data requirements of each model, (c) how the models can best be used in the weapon system acquisition process (WSAP), and (d) lastly, whether the models generate roughly equivalent results. In meeting these objectives, all three models are compared in terms of input requirements, method of processing, and output products. Volume I of this paper gives the analytic portion of the study. The results of the equivalence testing for the two average value

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models are included in Volume II. The second volume also contains a final section discussing the conclusions from the study.

A new average value model should be developed to work in conjunction with LCOM, incorporating the network tracing capability of the EVM and the variety of output of the R&M. This new model should include the average turn-around time computations and outputs for each flightline maintenance network. That could give design engineers an idea of the readiness capability of the weapon system early in the WSAP. As soon as a gross level maintenance network is ready for the complete projected weapon system, the LCOM simulation should be run to check out (a) interaction of maintenance on resource requirements and (b) the overall weapon system readiness capability.

AFHRL Technical Paper 82-12(I) June 1982

MAINTENANCE SUPPORT RESOURCE FORECASTING MODELS

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MAINTENANCE SUPPORT RESOURCE FORECASTING MODELS

I. INTRODUCTION

The Air Force Human Resources Laboratory (AFHRL) created the Maintenance Manpower Model which uses the Logistics Composite Modeling (LCOM) simulation software. It also has developed two average value models, the Reliability and Maintainability Model (R&M) and the Expected Values Model (EVM=EXPVAL). These three models basically address the same maintenance support resource needs--humans, spares, and equipment.

The objective of this study is to analyze these three models in terms of (a) how they relate to each other, (b) what the minimal data requirements are for each model, (c) how the models can best be used in the weapon systems acquisition process (WSAP), and (d) lastly whether the models generate roughly equivalent results.

In meeting these objectives, all three models are compared in terms of input requirements, method of processing, and output products. The analytic portion of this study is in this volume. Volume II gives examples and results of the equivalence testing for only the two average value models.

II. DESCRIPTION OF EACH MODEL

LCOM

LCOM is a very flexible *Monte* Carlo simulator. Written in the Simscript II.5 language, it is readily compatible on the Control Data Corporation (CDC), ITEL, and Honeywell computers. LCOM is widely used throughout the Air Force manpower community. It has dynamic core capability so that it expands or decreases the computer core requirements based on the network size and run specifications. A user can develop tailored distributions as inputs to LCOM. Although it has many uses, one of the more common is to predict the maintenance resource requirements (people, spares, and support equipment) in order to meet a given flight and environment scenario. A very powerful tool, it allows users to assess resource overloads and bottlenecks for periods as short as one-half hour time blocks. It also allows predictions of sortie generation capability for various maintenance and operating environments. LCOM is the only tool of the three models which predicts overall weapon system capability. See Reference 1 for detailed information pertaining to LCOM capability.

When used to determine system manpower requirements, LCOM is normally run with large data bases with run times and core requirements which force Aeronautical Systems Division (ASD) users to make off-hour runs, i.e., nights and weekends. The user makes several iterations of runs through LCOM to determine what effect a change in a particular constraint of resources will have on the readiness capability.

R&M

R&M is an average value model. It can be run with daytime turnaround. One of its main uses is to indicate clearly to design engineers which tasks for given equipment require high maintenance manhours. This allows the design decision makers to make trade-off studies basel on figures of merit. See References 2 and 3 for more information.

Written in FORTRAN, it is only partially compatible on the Honeywell and CDC computers. In order to get daytime turnaround, only 40 subsystems can be processed. The limit is reasonable when looking at the figures of merit for equipment which is suspected to have high maintenance resource demands. For an overview of the whole aircraft, this limit is too small. Only a restricted network structure is accepted for input, but most maintenance networks conform to that structure. The R&M model does <u>not</u> check maintenance time requirements against mission time constraints.

Although this report studies the R&M batch program as a stand alone program, it is also a part of the Coordinated Human Resources Technology (CHRT) which integrates five basic human resource technologies. Reference 4 describes CHRT. The CHRT flow diagram is seen in Figure 1. Note that the R&M is shown in ellipse #11. The R&M data base is used not only by the R&M model, but also as one of the inputs for the Reliability, Maintainability, and Cost Model (RMCM). Figure 2 displays a suggested interrelationship of RMCM and the Logistics Composite Cost Model (LCCM). Reference 5 gives the methodology of this proposed concept.

EVM

EVM is also an average value model. It can be run with daytime turnaround. EVM has been developed in conjunction with LCOM for a quick response of expected value maintenance manhour (MMH) and spare parts utilization capability. It has primarily functioned as a tool to debug LCOM maintenance networks with minimal core required.

EVM is presently available only in FORTRAN on the CDC computer. Tactical Air Command (TAC) is planning on implementing the EVM on the Honeywell computer. A conversion to Simscript II.5 has been proposed to make it available to all of the LCOM users. Just as for the R&M model, EVM does <u>not</u> match the delta maintenance aircraft turnaround times against the flying scenario to determine readiness capability. See References 6 and 7 for more information about EVM. Ellipse #10 in Figure 1 indicates the role that EVM (=EXPVAL) plays in the CHRT design. Figure 2 also shows how LCOM, R&M, and EVM could work together.

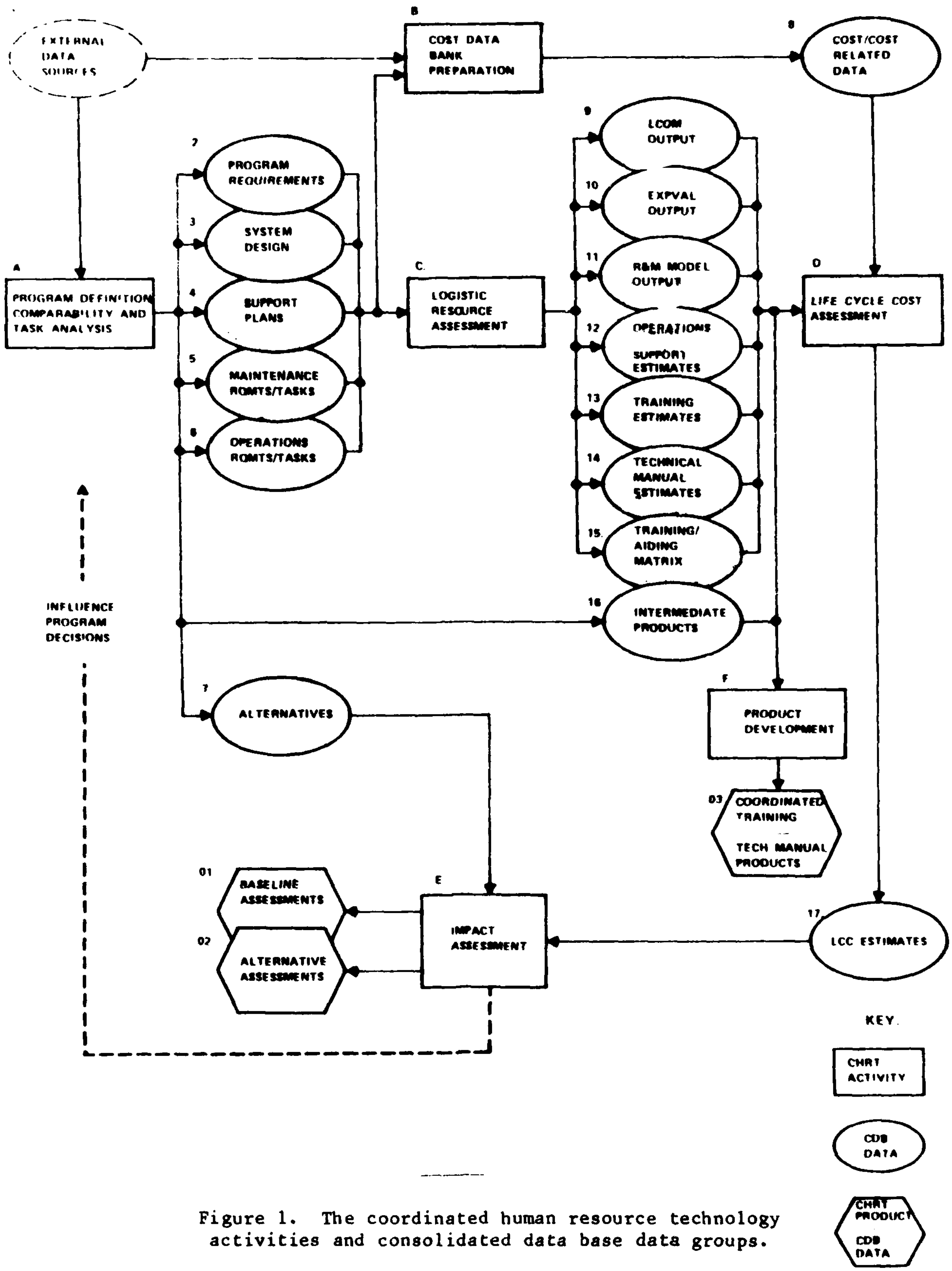

Figure 1. The coordinated human resource technology activities and consolidated data base data groups.

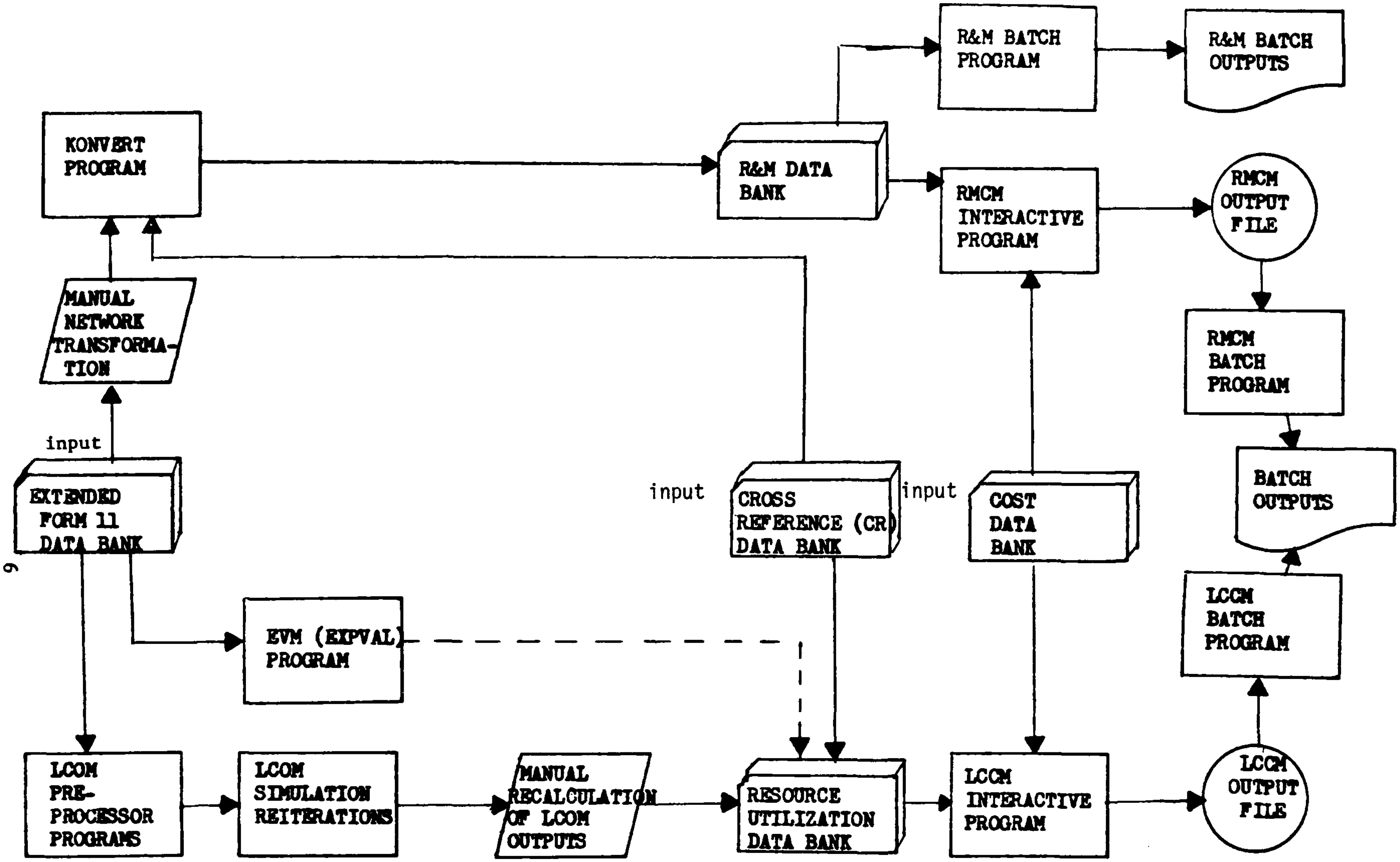

Figure 2. Interrelationship of RMCM and LCCM inputs.

III. COMPARISON OF MODELS

Inputs

Similarities. All three models need a maintenance-resource network data bank. All the time that personnel are occupied or unavailable for other work because of the requirement to accomplish a task is included in the task network. Only tasks that directly impact sortie generation and maintenance are normally networked. A common format for this required information is the Extended Form 11. This form was designed by AFHRL from several LCOM forms to simplify the manual coding process. Figure 3 shows a copy of the coding sheet with fields labelled. Briefly, each line of the data represents one maintenance task and its required resources. The prenode and next node show its position in the network. The selection mode and its probability indicate what kinds of decisions are to be made when arriving at that prenode in the network.

The main reason for interest in the input requirements of the three models is to determine at what points in the weapon systems acquisition process (WSAP) the required data are available. In order to establish even a very gross level-of-detail Extended Form 11 network, a first cut of the comparability analysis needs to be completed. The networker then has a rough idea of which black boxes on the proposed aircraft will be similar to black boxes on existing aircraft and can then gather the appropriate maintenance data and set up the first gross level of detail Extended Form 11.

Differences. EVM is the only model which uses the Extended Form 11 data bank directly. As changes are made in the preprocessor for LCOM, EVM is updated to use the Extended Form 11 in the same way.

EVM uses the terminology Aerospace Ground Equipment (AGE) while both the R&M and LCOM models use the name Support Equipment (SE) for the same item. These both are defined as powered or non-powered equipment used to support aircraft maintenance service and handling tasks. Examples would be: external electric carts, hydraulic power units, light-alls, B-1 and B-4 maintenance stands, and jack stands.

LCOM has a preprocessor called Phase I and II which generates most of the forms required for LCOM directly from the Extended Form 11. Additional inputs for LCOM may be given by the user such as the flying schedule, delay time limits before cancellation of missions, weather conditions, and probability spread corresponding with task times. This operations scenario information input is unique to LCOM. The average value models do not use it at all.

Note in Figure 4 that LCOM requires maintenance environment network data plus the operations scenario. EVM and R&M use only the maintenance environment network data as their input. Initially, the R&M model developers extracted the maintenance-resource data manually from the Extended Form 11 data base and transformed the data into the R&M data input format. A generalized maintenance action network was established as seen in Figure 5.

INPUT No. 2

EXTENDED FORM 11

Field	Card columns
	1–4
Prior Node	5–10
	11
ACT	12
WUC	13–17
	18
Next Node	19–24
HEADER	25
Sel. Mode	26
PUT DECIMAL MSBF or Probability	27–32
	33
NCLOK Clock No.	34–37
	38
Release	39
Type Task	40
Priority	41
	42
TIME (Tenths)	43–47
% VAR	48–50
Dist. Type	51
TIME UNIT	52
N	53
DEC(1) OR AFSC/AGE	54–58
	59
N	60
DEC(2) OR AFSC/AGE	61–65
	66
N	67
DEC(3) OR AFSC/AGE	68–72
	73
N	74
DEC(4) OR AFSC/AGE	75–79
Continuation	80

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PUNCH CARD TRANSCRIPT

Figure 3. Extended form 11.

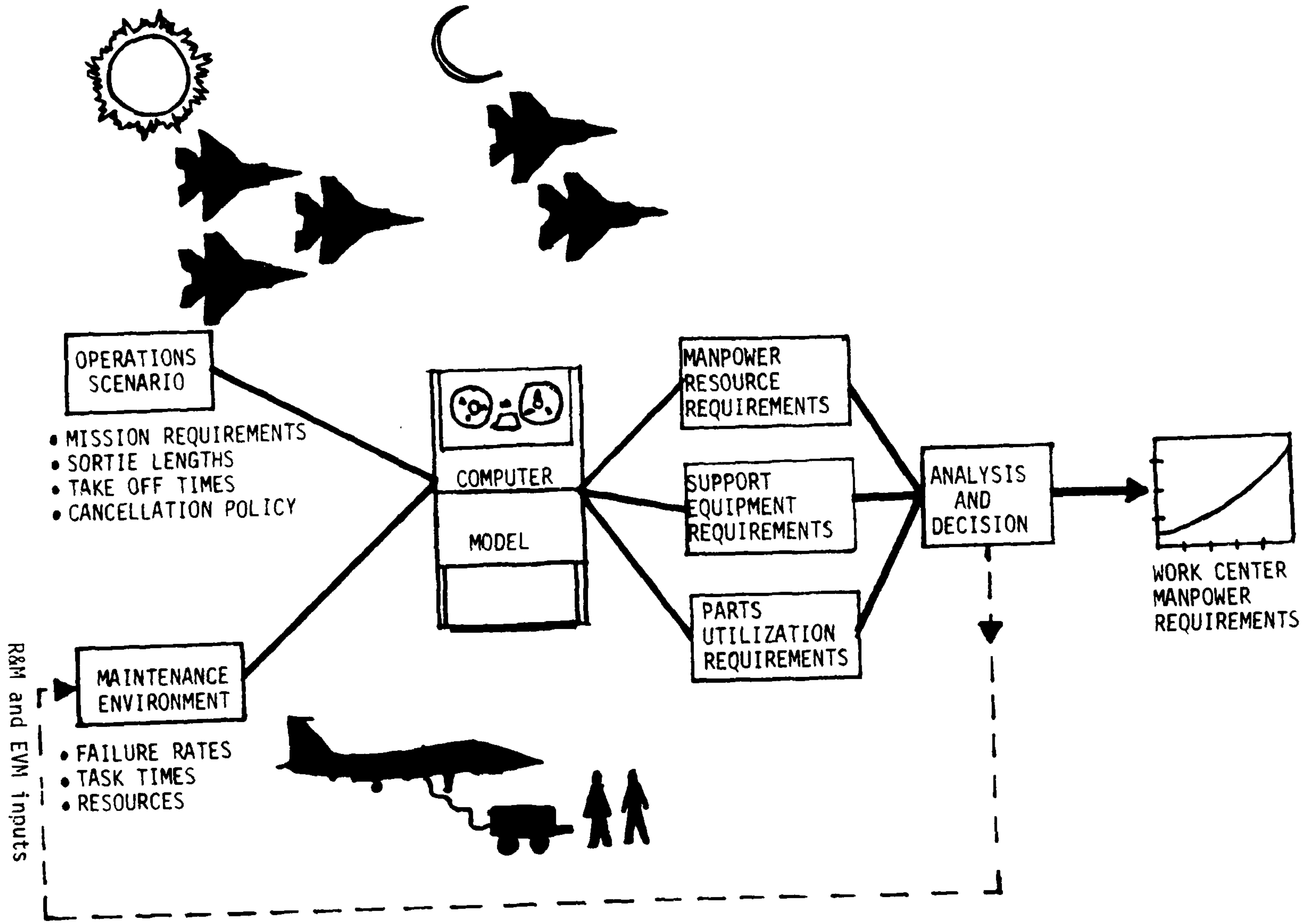
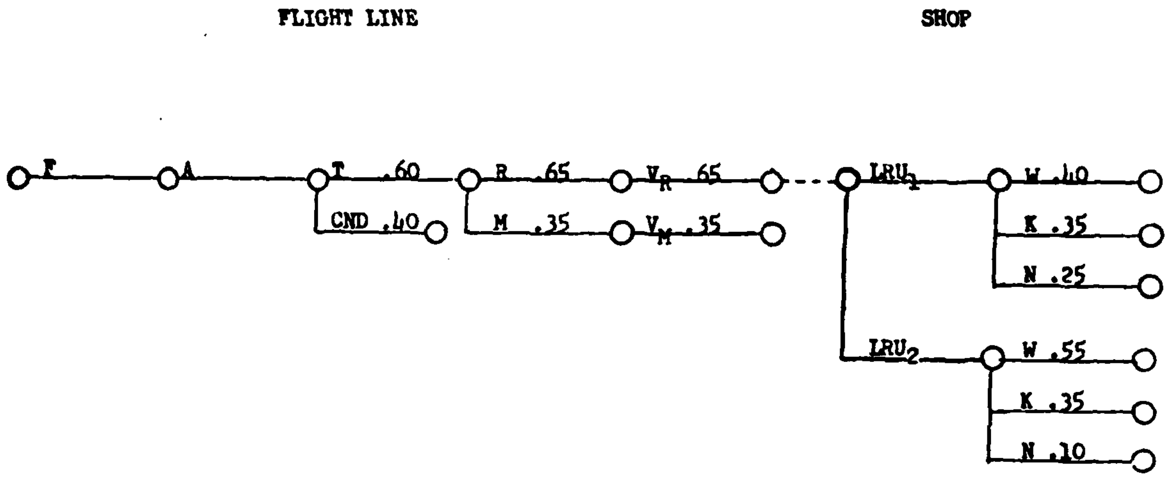


Figure 4. Example input and outputs for logistics models.



F = Failure clock
A = Set up AGE or SE
T = Troubleshoot
CND = Cannot Duplicate
R = Remove/Replace
M = Minor maintenance
V = Verify
W = Workbench repair
K = Bench check OK
N = NRTS, i.e., not repairable this station

Figure 5. Generalized maintenance action network.

This allows only seven task types on the flight line and three task types per LRU (line replaceable unit) in the shop. Figure 6 shows test station and test drawer networks which were added later in the development of the R&M model. At the nodes where split-offs occur, certain kinds of selection modes are presumed as marked on Figure 5. In LCOM terminology, E selection mode means mutually exclusive probabilities and G (which is similar to the A) selection mode is an independent probability.

A preprocessor, KONVERT, was written to automate this conversion of Extended Form 11 data to R&M data format. See Reference 4 to learn about KONVERT. Figure 2 shows where KONVERT fits into the data flow from the Extended Form 11 to the R&M data base. Unfortunately, KONVERT has not been maintained to keep pace with the changes in the R&M data base.

The maintenance networks of five subsystems were manually converted from the Extended Form 11 which EVM uses to the R&M data base format for this comparison study. Although the various card input types are grouped together across all subsystems in the R&M data base, the example in Volume II, Appendix A, of the R&M input for the five subsystems has been grouped by subsystem input requirements.

Also required for the R&M model is a cross-reference (CR) file. It indicates among other things, the number of LRUs in a subsystem, and the number of SRUs (shop replaceable units) in an LRU. R&M uses this for establishing the size of its matrices. Other CR information such as the physical weight of an LRU and the QPA (quantity per application) is used by RMCM, but not by R&M.

Method of Processing

Average Value. Both the EVM and R&M are average value models. They compute expected values by working through every path of a maintenance action network. The probability of occurrence for a given task is the product of the probabilities of each task in the branch up to the given task.

For example, the probability of occurrence for the Remove and Replace Verification task in Figure 5 is computed as:

$$1.00 \times 1.00 \times .60 \times .65 = .39$$

For that task, its average duration is multiplied by the probability of occurrence to obtain the expected mean time to repair (MTTR) the item. The MTTR in turn is multiplied by the crew size giving the expected maintenance manhours (MMH) needed for that task. If a certain kind of SE is required to do the task, then the MTTR is also the expected SE utilization time.

The number of times a failure for a subsystem occurs is computed in the R&M by dividing 1000 flight hours by the mean flight hours between maintenance

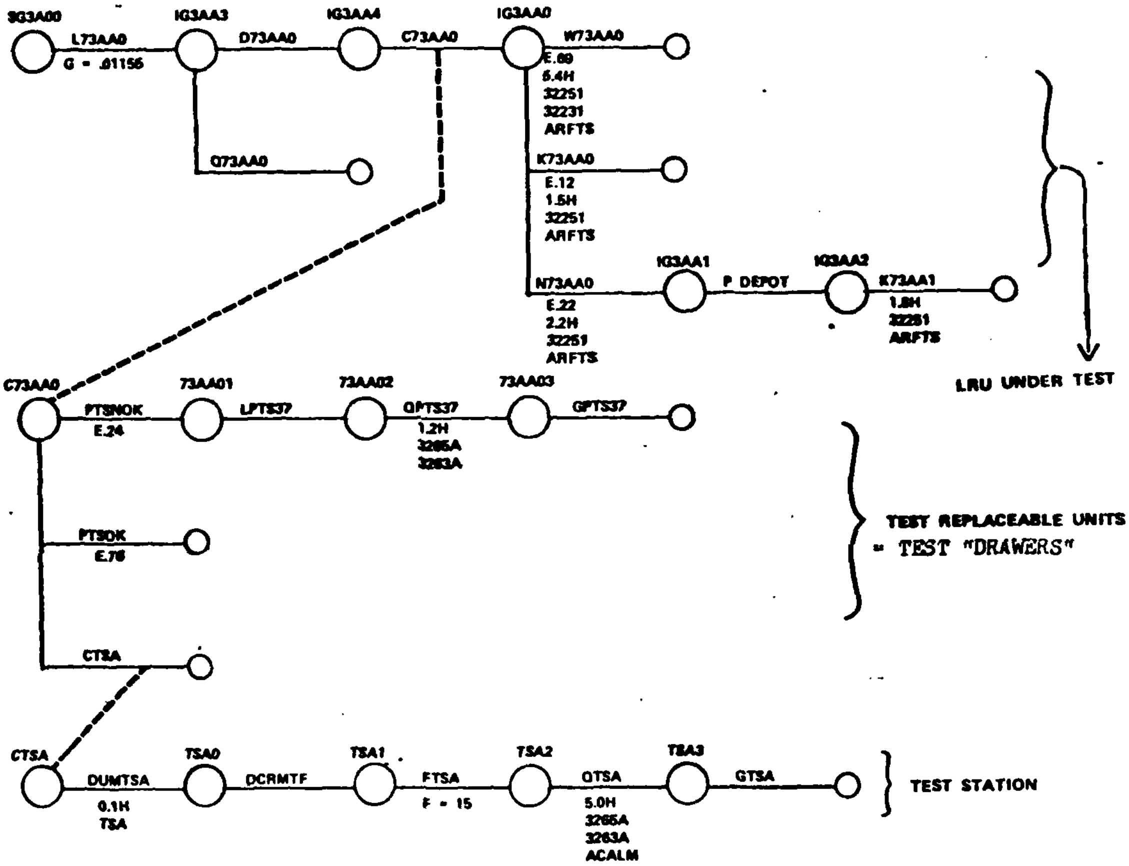


Figure 6. Sample of a combined LRU and test station test network diagram for the R&M model.

actions (MFHBMA). The EVM computes this number of expected failures by dividing the number of sorties for a given period by the mean sorties between failures (MSBF). (The EVM user has the option of using other failure driver inputs for a given maintenance action network, such as rounds fired or flight hours.) The MTTR, MMH, and SE utilization time is multiplied by this number (the number of times the maintenance network is expected to be required) to give the expected values for the time period in which that number of flying hours/sorties took place.

Both the R&M and the EVM models can compute expected values of maintenance resource requirements for as few as one subsystem network. R&M can process as many as 40 subsystems. EVM can usually handle the total maintenance action network, including flight line and phase maintenance. Neither average value model shows any effect that the maintenance requirements of one subsystem have on the maintenance of another. The average value models can be run in the early WSAP as soon as a trade-off study for one maintenance action network is prepared.

The computation of these expected values does not take into consideration that only a certain number of spare parts, SE, or skilled people may be available at a certain time. In manpower terminology, this processing accepts 100% deferrable maintenance and an unconstrained resource pool. That means either (a) that the delay time for the right resources to be available is not taken into consideration on mission time constraints or (b) that the required resources are readily available. The EVM and R&M models do not take into account readiness requirement peaks. But, these average value models may indicate the very infrequent need for a specialist who might not show up in several LCOM runs because of the small probability that such a specialist would be required. Conversely, the EVM and R&M models may indicate less than the number of people actually needed because they do not account for queuing and peak work loads. These could be included in an LCOM run.

Dynamic Simulation-LCOM. LCOM is a Monte Carlo simulator. The Exogenous input file (the flying schedule, mission cancellation delay time, weather conditions, and preparation lead time file) drives the simulation which has already been defined in the Initialization input file (the maintenance network and resource requirements file, derived from observed data). An example follows of how this support maintenance work is simulated in the Main Module. See Figure 7 to follow the flow of the example.

For example, if four brand X aircraft are needed for a mission to takeoff at 10 am and the preparation lead time is 2 hours, then at 8 am a check is made to determine if four brand X aircraft are available in the aircraft pool. If they are, then pre-sortie maintenance tasks are started. Usually the network is set up to check for critical failures. Whatever is most directly related to the failure of a piece of equipment is called its failure driver. LCOM simulates a failure by using a failure counter or "failure clock." The LCOM user usually sets the failure clock to the MSBF value for each piece of equipment handled on the flight line. During the simulation, LCOM tracks the status of an item by decrementing the failure clock each time a failure event

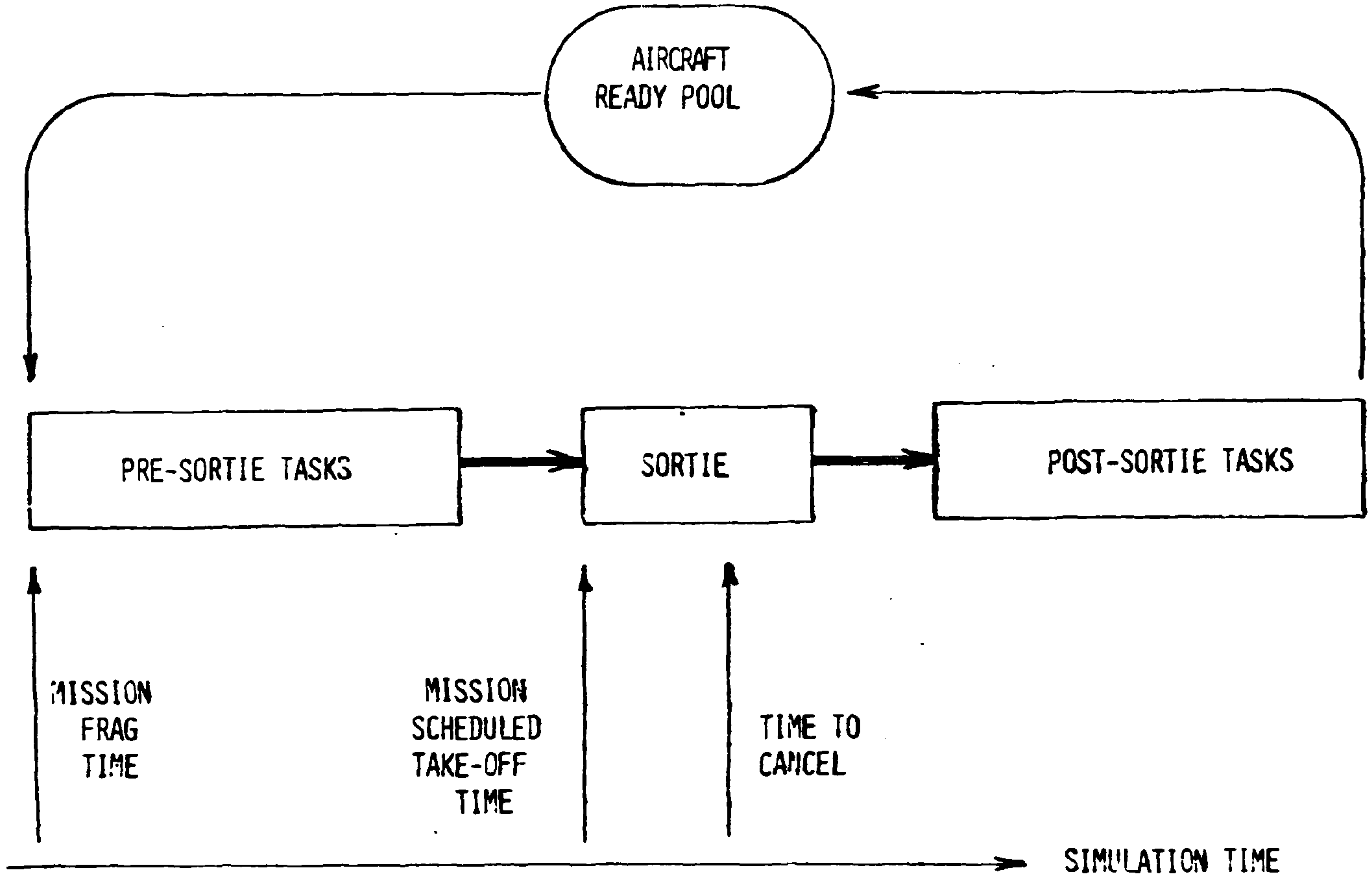


Figure 7. Main module flow logic - LCOM.

(i.e., sortie) occurs. When the failure clock is checked and found to be zero or less, a simulated failure has been discovered. At that point the maintenance network for that item is entered, and the failure clock is reset.

The user may choose to set up sorties (landings) as the driver of landing gear failures and to set up the clock to keep track of the number of sorties for landing gear. The failure rate would be expressed in terms of MSBF. Each time a sortie occurs, the failure clock is decremented. When the failure clock is checked and found to be zero or less, the maintenance network for the landing gear is entered, and the failure clock is reset to the MSBF value.

See Figure 5 to follow this example. Suppose that in Preflight preparation it is discovered that the landing gear has a failure for one of the four brand X aircraft. The simulator enters the maintenance action network for the landing gear. In the meantime, it continues preparing the other three aircraft for the mission. Each task starting with a (Set up SE) has certain required resources of skilled people, SE, spare parts, and average task time listed. LCOM checks to see what path it is to take. Initially, there is only one choice. Next, it looks at the pool for each required resource.

In the example, if a jack is needed for fixing the landing gear, then LCOM tries to obtain a jack from the SE pool. If a person of skill code Y is needed, then LCOM looks into the manpower pool. Suppose a jack is available, but the specially trained required person is not. Then LCOM checks the priority of the task which it is attempting to start and compares that with the priorities of other tasks currently in process which also require a skill code Y person.

Presume that this new task has a higher priority, and a skill code Y person is temporarily pulled off another job. If requested by the user, a line of manpower back order data is written to a file showing the time of day and for how long a task was delayed for want of this skilled person. When the new task is completed, that skilled person returns to the other task. At task completion, the clock is advanced from the start time (8 am in this example) forward by the amount of time it took to do the task. LCOM uses stochastic distributions to determine this task time value if so instructed. The task time determination is based on what distribution scheme is specified by the networker.

At the next node in Figure 5, where the network branches to Troubleshoot or Cannot Duplicate, a decision is made concerning which path to take. This is another point where the Monte Carlo aspect comes into the simulation. At this point, a random number draw is made. Suppose that it went with the troubleshooting task. The same procedure is followed as for the first task.

For this purpose, suppose that the required skilled person is not in the manpower pool and is not accessible from another task (because this troubleshooting priority is the same or lower). Again, if specified, a line of back order data is produced to show this deficiency. The repair of the landing gear is delayed until all required resources are available. If the

delay is too long, the mission is in jeopardy of being cancelled. If the mission requirement had been entered that four brand X aircraft were to be prepared but the mission could take off at 10 am if at least three were ready, then this would not have been critical.

This simple example shows some of the capabilities of LCOM. LCOM accepts many input forms that allow the user great flexibility. It can be used to answer many different questions.

Because of the random nature of selecting paths, task durations, and so forth, making LCOM runs with the same basic input data but with a different random seed input will always result in some variations in output. Where this output variation is considerable, the user normally increases the simulation run length to reach a steady-state condition. When the results of the variations stabilize, LCOM runs are made to fine-tune constraints on resources.

In order to determine the readiness capability of an aircraft, all of the critical maintenance action networks must be present for an LCOM run. LCOM does check for interaction of maintenance efforts. For example, the manpower, spares, and SE pools are checked each time they are needed. As mentioned, if the required resources are tied up somewhere else for a lower priority task, the manpower and task and SE are preempted from that lower priority job temporarily. Spares are sometimes obtained by cannibalizing from other aircraft.

Output

Average Value-R&M, EVM. EVM has a very simple average value output as seen in Figure 8. Expected MMH for a given calendar time period are listed by on- and off-equipment. These MMH are listed for each type of skilled person Air Force Specialty Code (AFSC) by work unit code (WUC), i.e., "black box," and then in a final summary. Any support equipment (SE = AGE) which is required has a utilization time indicated. As is standard for users of the Extended Form 11, the AFSC always starts with a number and AGE (or SE) starts with a letter. The consumption of a part is flagged on the Extended Form 11 by having a Q action code. Its expected frequency of utilization is printed as an output.

An optional output is a line printer plot. Since EVM is not restricted to using a compressed generalized maintenance action network with a fixed structure, it is often worthwhile to plot complex networks. See Figure 9 for an example of the plot. LCOM has an auxiliary program which also plots on the Calcomp Plotter either from the Extended Form 11 or from the LCOM forms input.

R&M, in contrast to the EVM, has many more options of printouts. The R&M output focuses on figures of merit which appear most useful to engineers and managers who need to make early decisions based on design trade-offs. The most elaborate printout attempts to show what portion of the flight line (= on equipment) subsystem maintenance is related to shop actions on LRU's (see

WUC	423X0	423X1	431R1	....	431P1	427X5	431X1	AFSC TOTAL	AGE TOTAL
1114*									
ON	51.03	.04	.61	0.00	.29	.06	.18	52.22	0.00
OFF	.39	0.00	0.00	0.00	0.00	.23	0.00	.63	0.00
ACC									
ON	62.99	.04	75.51	0.00	6.92	32.30	61.96	239.71	0.00
OFF	46.78	0.00	0.00	0.00	0.00	12.30	0.00	59.08	0.00
WUC SUM	51.42	.04	.61	0.00	.29	.30	.18	52.84	0.00
ACC SUM	109.77	.04	75.51	0.00	6.92	44.59	61.96	298.79	0.00

```
PART = Q11141 HAS ACTION TAKEN CODE OF Q WITH ACCUM. FREQUENCY =    .23418 FOR NCLOK = 1114*
PART = Q11145 HAS ACTION TAKEN CODE OF Q WITH ACCUM. FREQUENCY =   1.08415 FOR NCLOK = 1114*
PART = Q11144 HAS ACTION TAKEN CODE OF Q WITH ACCUM. FREQUENCY =   2.47187 FOR NCLOK = 1114*
PART = Q11143 HAS ACTION TAKEN CODE OF Q WITH ACCUM. FREQUENCY =    .15612 FOR NCLOK = 1114*
PART = Q11140 HAS ACTION TAKEN CODE OF Q WITH ACCUM. FREQUENCY =    .15612 FOR NCLOK = 1114*
PART = Q11142 HAS ACTION TAKEN CODE OF Q WITH ACCUM. FREQUENCY =    .07806 FOR NCLOK = 1114*
PART = Q11146 HAS ACTION TAKEN CODE OF Q WITH ACCUM. FREQUENCY =    .15612 FOR NCLOK = 1114*
```

Figure 8. Examples of expected monthly resource demands.

EXPECTED 4-WEEK RESOURCE SUMMARY FOR T37

	423X0	431R1	427X5	....	427X0	427X1	431X1	431P1	423X2	427X2
ON	63.75	89.65	44.15	0.0	7.67	261.15	67.92	12.42	27.95	.28
OFF	46.78	0.00	26.26	0.0	4.17	0.00	0.00	0.00	0.00	0.00
ACC	110.53	89.65	70.41	0.0	11.84	261.15	67.92	12.42	27.95	.28

DUALA	427X4	431W1	423X1
.09	0.00	0.00	.04
0.00	6.18	.43	0.00
.09	6.18	.43	.04

Figure 8. Examples of expected monthly resource demands (Concluded)

```
(1 )F 548.(1 )A .261
   F1114*  / V11140
           /    .80
           / 2423X0
           /
         (1 )A .107
           / V11141
           /    .50
           / 1423X1
           /
         (1 )A .761
           / T11140
           /   1.40
           / 2423X0
           /
         (1 )A .014
           / T11141
           /   1.90
           / 2431X1
           /
         (1 )E .145
           / H11140
           /    .81
           / 2423X3
           /
         (1 )E .442(2 )E .410(3 )D ....(4 )A .295
           / JDUMY1  / T11142    M11140    V11142
           /         /             1.00
           /         /           2423X0
           /         /
           /       (2 )E .590(3 )SEE
           /           NOTSHT    ABOVE
           /
         (1 )E .008.............................(5 )D ....(6 )D ....(7 )D ....
           / JDUMY1                                 T11143    M11141    V11143
           /                                                     .80
           /                                                 1423X0
           /                                                 1431P1
           /
```

Figure 9. Example of network plot-input from ANG.

```
(1 )E .007..............................................................(8 )D ....
  / JDUMY1                                                                 M11142
  /                                                                           .40
  /                                                                        2427X5
  /
(1 )E .007........................................................................(9 )D ....(A )D ....
  / JDUMY1                                                                            M11143    V11144
  /                                                                                     .20
  /                                                                                   1431P1
 ./
(1 )E .114...... ..................................................................................(B )D ....
  / JDUMY1                                                                                          M11144
  /                                                                                                    .50
  /                                                                                                 1431X1
  /
(1 )E .377.........................................................................................(C )-
    JDUMY1
```

Figure 9. Example of network plot-input from ANG (Continued)

```
(C )E .923(D )E .771(E )D ....(F )E .208...............................(40)D ....(41)E .054(42)I ....
  / JDUMY1  / T11144    R11140  / V11145                                   SHOP    /         / Q11141
  /         /             1.10  /                                                  /         /
  /         /           2423X0  /                                                  /         /
  /         /                   /                                                  /         /
  /         /                   /                                                  /       (42)D ....(43)E .333
  /         /                   /                                                  /          *G11141  / W11141
  /         /                   /                                                  /                   /   1.00
  /         /                   /                                                  /                   / 1427X5
  /         /                   /                                                  /                   /
  /         /                   /                                                  /                 (43)E .667
  /         /                   /                                                  /                     JNSHOP
  /         /                   /                                                  /
  /         /                   /                                                (41)E .250....................(44)I ....
  /         /                   /                                                  / JDUMY1                      / Q11145
  /         /                   /                                                  /                             /
  /         /                   /                                                  /                           (44)D ....(45)-
  /         /                   /                                                  /                              *G11145
  /         /                   /                                                  /
  /         /                   /                                                (41)E .570..............................(46)-
  /         /                   /                                                  / JDUMY1
  /         /                   /                                                  /
  /         /                   /                                                (41)E .036..............................(48)-
  /         /                   /                                                  / JDUMY1
  /         /                   /                                                  /
```

Figure 9. Example of network plot-input from ANG (Continued)

```
  /         /                   /                                               (41)E .036..............................(4A)-
  /         /                   /                                                 / JDUMY1
  /         /                   /                                                 /
  /         /                   /                                               (41)E .018..............................(4C)-
  /         /                   /                                                 / JDUMY1
  /         /                   /                                                 /
  /         /                   /                                               (41)E .036..............................(4E)-
  /         /                   /                                                 / JDUMY1
  /         /                   /
  /         /                 (F )E .792..............................(40)SEE
  /         /                     NOVFFY                                  ABOVE
  /         /
  /       (C )E .229(E )SEE
  /           NOTSHT    ABOVE
  /
(C )E .919..............................(G )D ....(H )D ..............(40)SEE
  / JDUMY1                                  R11141    V11146              ABOVE
  /                                           1.20
  /                                         2431P1
  /
(C )E .058..................................................(I )D ....(40)SEE
    JDUMY1                                                      R11142    ABOVE
                                                                   .40
                                                                1431X1
```

Figure 9. Example of network plot-input from ANG (Concluded)

Figures 10 and 11). Note that in both examples, the seven flight line tasks of the generalized maintenance action network (Figure 5) are the headers across the top. In addition to these detailed level figures of merit, there are various levels of summary reports. Note that no spare parts consumption output is produced by R&M.

One of the most confusing aspects of looking at R&M output after being acquainted with EVM output is the SE. The flight line SE report indicates the utilization time of that piece of SE (as in the EVM output), while the shop SE reports the time it takes to repair the test drawer and test station (SE). See Figure 6 for the shop network which includes the test drawer and test station network. Refer to Reference 8 for more information on this topic.

Although the expected values computed in the average value models are "ball park" figures only, they can be useful in studying trade-offs in design possibilities throughout the WSAP. LCOM should be used in order to check for major pitfalls into which the expected value answers can lead an uncautious user.

Dynamic Simulation-LCOM. Figure 12 shows the data flow for processing LCOM models. The printed outputs will be discussed in this section. Since LCOM does check for interaction of maintenance efforts, its outputs are much more complex than those of the average value models.

The primary function of the Input Module is to translate user supplied data into a form which can be used by the Main Module of the LCOM Simulation Software. The user provided information is transcribed onto punched cards or permanent files to form the "input data." The Input Module performs two major functions as it reads this input data: it edits and converts the data into the initial conditions file generally called the "Initialization" file. Simultaneously, extensive error checking and diagnostic messages are performed to notify the user of input data errors, omissions, and inconsistencies if there are any. The Exogenous file, which contains the flying schedules, is the final important product of the Input Module. See Figure 12 for the flow of data for the Input Module.

There are several reports available directly from the Main Simulation Module. Except for default values for the Performance Summary Report (PSR), the other Main Module reports must be specifically requested in the Main Run deck. A user who wants to take advantage of one or more of the Post Processor programs must also indicate this in the Main Run deck so that the appropriate data will be sent to the Post Processor File while the simulation is processing.

The PSR indicates how well the simulation was able to maintain and prepare aircraft for the flight scenario (see Figure 13). The rest of the Main Module reports by column headings, numbers which are indices to the dictionary and control tables established in the Input Module. The Aircraft Configuration Status Report, Personnel, In-Process and Backorder Status Report, plus some Programmer Level Reports, are used primarily for validating the results of the

MTTR AS % OF TOTAL

SUBSYSTEM- AC320 (63A00) UHF RADIO SET MFHBMA= 62.9

	AGE F/L	TS/FL	R+R	VR+R	CND A/C	M A/C	VM A/C	SHOP	TOT/OUT
LRU- AC321 (63AA0) RECEIVER/TRANSMITTER (UHF)									
W	2.419	2.419	16.933	6.047				60.474	88.293
K	0.105	0.105	0.736	0.263				0.736	1.944
N	0.105	0.105	0.736	0.263				0.683	1.892
SUB	2.629	2.629	18.404	6.573				61.893	91.129
LRU- AC322 (63AE0) DIPLEXER									
W	0.028	0.028	0.197	0.070				0.113	0.436
K	0.	0.	0.	0.				0.	0.
N	0.003	0.003	0.022	0.008				0.016	0.053
SUB	0.031	0.031	0.219	0.078				0.129	0.489
LRU- AC323 (63AL0) STANDING WAVE RATIO INDICATOR									
W	0.019	0.019	0.130	0.046				0.546	0.760
K	0.	0.	0.	0.				0.	0.
N	0.019	0.019	0.130	0.046				0.065	0.278
SUB	0.037	0.037	0.259	0.093				0.611	1.037
CND	0.463				1.853				2.316
N	0.403	0.403				2.216	1.007		4.029
SUB	3.564	3.100	18.883	6.744	1.853	2.216	1.007	62.633	100.000

Figure 10. Sample option 02 report.

MMH AS % OF TOTAL

SUBSYSTEM- AC320 (63A00) UHF RADIO SET MFHBMA= 62.9

	AGE F/L	TS/FL	R+R	VR+R	CND A/C	M A/C	VM A/C	SHOP	TOT/OUT
LRU- AC321 (63AA0) RECEIVER/TRANSMITTER (UHF)									
W	2.878	1.439	10.073	3.597				71.948	89.935
K	0.125	0.063	0.438	0.156				0.438	1.219
N	0.125	0.063	0.438	0.156				0.406	1.188
SUB	3.128	1.564	10.948	3.910				72.792	92.341
LRU- AC322 (63AE0) DIPLEXER									
W	0.033	0.017	0.117	0.042				0.067	0.276
K	0.	0.	0.	0.				0.	0.
N	0.004	0.002	0.013	0.005				0.010	0.033
SUB	0.037	0.019	0.131	0.047				0.077	0.310
LRU- AC323 (63AL0) STANDING WAVE RATIO INDICATOR									
W	0.022	0.011	0.077	0.028				0.325	0.463
K	0.	0.	0.	0.				0.	0.
N	0.022	0.011	0.077	0.028				0.039	0.176
SUB	0.044	0.022	0.154	0.055				0.364	0.639
CND	0.551				2.204				2.755
N	0.479	0.240				2.637	0.599		3.955
SUB	4.240	1.844	11.233	4.012	2.204	2.637	0.599	73.232	100.000

Figure 11. Sample option 04 report.

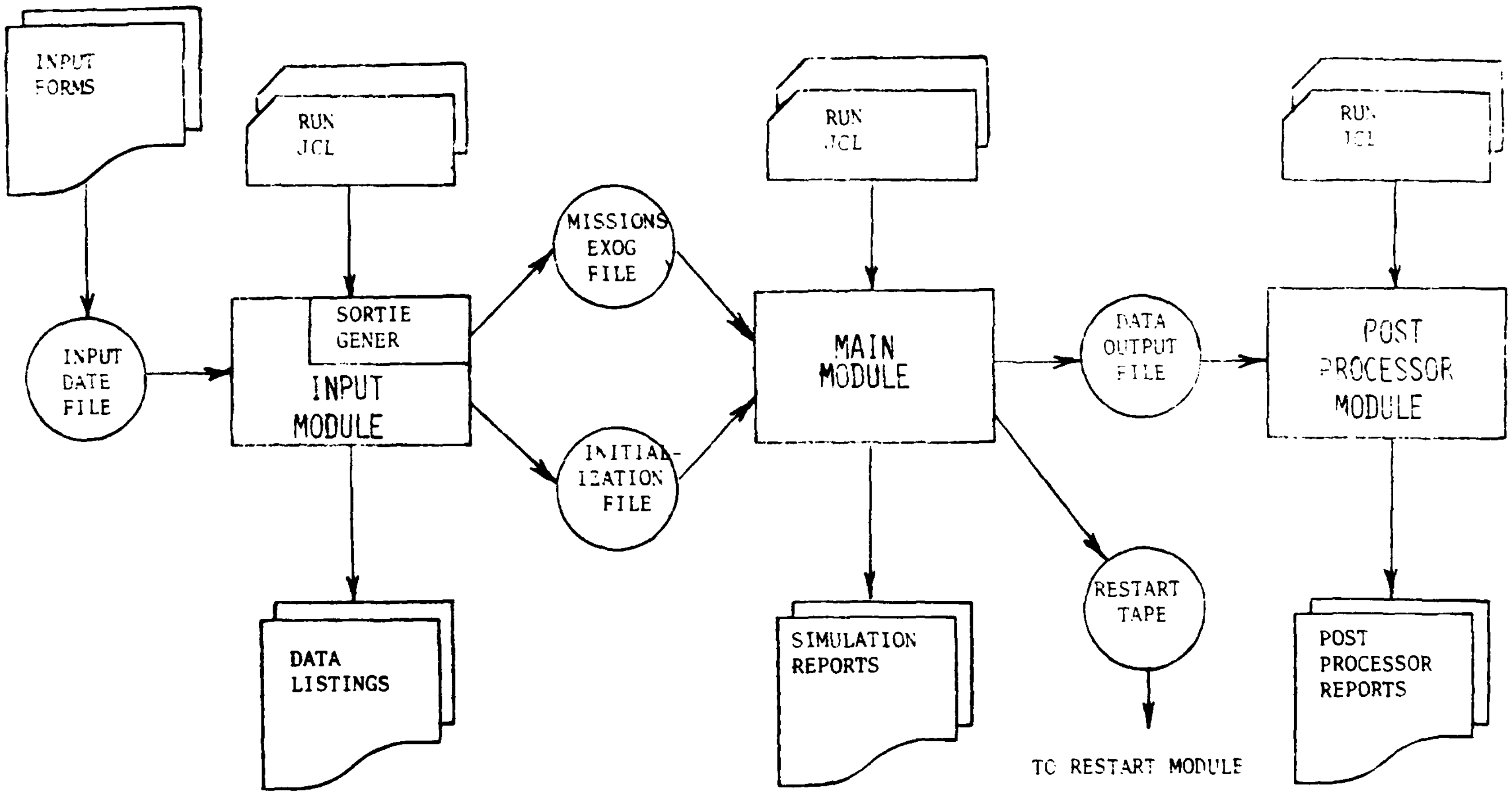


Figure 12. Basic LCOM II simulation software module interfaces.

RUN NUMBER SP4.0C   P E R F O R M A N C E   S U M M A R Y   PERIOD FROM 40.0 to 50.0   LEVEL 1

	M I S S I O N S	TOTAL	RECON	INTRD1	CLSPT1	CLSPT2	INTRD2	INTRD3	FERRY1	FERRY2	OTHER
1	NUMBER OF MISSIONS REQUESTED	149.00	70.00	20.00	10.00	10.00	10.00	10.00	10.00	9.00	0.
2	NUMBER ACCOMPLISHED	146.00	68.00	20.00	10.00	10.00	9.00	10.00	10.00	9.00	0.
3	PERCENT ACCOMPLISHED	97.99	97.14	100.00	100.00	100.00	90.00	100.00	100.00	100.00	0.
5	NUMBER OF SORTIES REQUESTED	268.00	100.00	40.00	30.00	40.00	20.00	10.00	10.00	18.00	0.
7	NUMBER ACCOMPLISHED	260.00	96.00	40.00	28.00	40.00	18.00	10.00	10.00	18.00	0.
8	PERCENT ACCOMPLISHED	97.01	96.00	100.00	93.33	100.00	90.00	100.00	100.00	100.00	0.
T1	NUMBER OF WEATHER CANCELS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
T2	NUMBER OF WEATHER DELAYS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
T3	NUMBER OF ALERT REPLENISHMENT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
T4	NUMBER OF ATTRITIONS	2.00	0.	0.	0.	0.	2.00	0.	0.	0.	0.
T5	NUMBER OF RAW REPAIRS	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
T6	NUMBER OF AIR ABORTS(TOTAL)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
C1	AVG. AC POST SORTIE TIME (HRS)	4.13	3.86	3.82	3.33	3.62	3.97	3.74	3.44	8.79	0.
C2	NO. OF POST SORTIES COMPLETED	260.00	96.00	40.00	28.00	40.00	16.00	10.00	10.00	20.00	0.

	A C T I V I T I E S	TOTAL	PREFELT	OTHER
A1	NO. OF ACTIVITIES REQUESTED	240.00	240.00	0.
A2	NO. OF ACTIVITIES STARTED	238.00	238.00	0.
A3	NO. OF ACTIVITIES CANCELLED	2.00	2.00	0.
A4	AVG. TIME TO GET RESOURCE (HRS)	.03	.03	0.

	A I R C R A F T	TOTAL	F4D	F4D.1	OTHER
13	NUMBER OF AIRCRAFT AUTH.(EOP)	18.00	15.00	3.00	0.
14	NUMBER OF AIRCRAFT-DAYS AVAIL	188.17	158.17	30.00	0.
15	PCT SORTIES(INCL ALERT)	6.92	7.17	5.62	0.
16	PCT UNSCHED MAINTENANCE	18.41	20.33	8.28	0.
17	PCT SCHED MAINTENANCE	10.79	11.73	5.84	0.
18	PCT NMCS	1.61	1.73	.95	0.
19	PCT MISSION WAIT STATUS	8.50	9.22	4.70	0.
20	PCT SERVICE + WAITING	3.49	1.95	11.59	0.
21	PCT OPERATIONALLY READY	50.29	47.88	63.01	0.
22	AVG. AC POST SORTIE TIME (HRS)	4.13	3.74	8.79	0.
23	AVG. NO. OF SORTIES/ A/C /DAY	1.38	1.53	.60	0.
24	FLYING HOURS	312.55	272.09	40.47	0.
T7	NUMBER OF FCF TASKS FLOWN	0.	0.	0.	0.
T8	AVG. AC PRESORTIE TIME (HRS)	1.52	1.58	.81	0.

Figure 13. Main module performance summary report (Level 1) - S.P. 4.0.

RUN NUMBER SP4.0C   P E R F O R M A N C E   S U M M A R Y   PERIOD FROM 40.0 to 50.0   LEVEL 1

	P E R S O N N E L	TOTAL	CREWC	OMPER	FLTEN	HYDTK	HYDSP	COMTK	COMSP	MUNSP	CAMTK	GENTK
27	MANHOURS AVAILABLE (100)	114.60	12.80	17.60	3.20	1.60	4.80	15.20	16.80	28.00	5.00	0.
28	PERCENT UTILIZATION	33.72	22.02	39.87	29.00	11.01	17.10	57.47	47.56	32.94	17.27	0.
29	MANHOURS USED (100)	38.64	2.82	7.02	.93	.18	.82	8.74	7.99	9.22	.86	0.
30	PCT UNSCHED MAINT. OF STAT 29	74.99	.74	4.86	98.65	100.00	97.97	99.42	99.76	99.74	100.00	0.
31	PCT SCHED MAINT. OF STAT 29	25.01	99.26	95.14	1.35	0.	2.03	.58	.24	.26	0.	0.
P1	PCT PRIME OF STAT 29	96.62	74.60	99.66	98.65	75.98	52.83	99.08	99.76	99.74	100.00	0.
P2	PCT SUBSTITUTE OF STAT 29	3.38	25.40	.34	1.35	24.02	47.17	.92	.24	.26	0.	0.
33	NUMBER OF MEN DEMANDED	6790.00	404.00	1496.00	212.00	56.00	95.00	1325.00	1786.00	956.00	182.00	238.00
P3	NO OF MEN DEMANDED POST SCAN	6790.00	482.00	1418.00	212.00	30.00	107.00	1301.00	1786.00	956.00	182.00	276.00
34	% AVAIL BY OH. BAL. OF RES	88.62	96.27	92.38	88.68	76.67	85.05	86.47	95.91	93.10	95.05	0.
35	% AVAIL BY GEN SUBS OF RES	4.18	0.	0.	0.	10.00	8.41	0.	0.	0.	0.	98.55
36	% AVAIL BY EXPEDITE PROC.	.15	.62	0.	0.	0.	0.	0.	0.	0.	1.65	1.45
37	% AVAIL BY PREEMPTION PROC.	.03	.41	0.	0.	0.	0.	0.	0.	0.	0.	0.
38	% DEMANDS NOT AVAIL FOR RES	7.03	2.70	7.62	11.32	13.33	6.54	13.53	4.09	6.90	3.30	0.
39	OVERTIME MANHOURS USED (100)	.12	.01	0.	.00	0.	0.	.04	.01	.05	.00	0.
40	SIMULATED MH PER FLYING HOUR	12.36	.90	2.25	.30	.06	.26	2.80	2.56	2.95	.28	0.

	P E R S O N N E L	TOTAL	OMPERB	OTHER
27	MANHOURS AVAILABLE (100)	114.60	9.60	0.
28	PERCENT UTILIZATION	33.72	.71	0.
29	MANHOURS USED (100)	38.64	.07	0.
30	PCT UNSCHED MAINT. OF STAT 29	74.99	0.	0.
31	PCT SCHED MAINT. OF STAT 29	25.01	100.00	0.
P1	PCT PRIME OF STAT 29	96.62	100.00	0.
P2	PCT SUBSTITUTE OF STAT 29	3.38	0.	0.
33	NUMBER OF MEN DEMANDED	6790.00	40.00	0.
P3	NO OF MEN DEMANDED POST SCAN	6790.00	40.00	0.
34	% AVAIL BY OH. BAL. OF RES	88.62	100.00	0.
35	% AVAIL BY GEN SUBS OF RES	4.18	0.	0.
36	% AVAIL BY EXPEDITE PROC.	.15	0.	0.
37	% AVAIL BY PREEMPTION PROC.	.03	0.	0.
38	% DEMANDS NOT AVAIL FOR RES	7.03	0.	0.
39	OVERTIME MANHOURS USED (100)	.12	0.	0.
40	SIMULATED MH PER FLYING HOUR	12.36	.02	0.

Figure 13. Main module performance summary report (Level 1) - S.P. 4.0 (continued)

RUN NUMBER SP4.0C   P E R F O R M A N C E   S U M M A R Y   PERIOD FROM 40.0 to 50.0   LEVEL 1

	S H O P R E P A I R	TOTAL	PMPH1	PMPH2	RDASY	RDC11	RDC12	BM500	SMTBM	MISLS	CAMRA	OTHER
44	NO. OF REP GENS OR EXCG DMDS	1307.00	4.00	11.00	193.00	118.00	131.00	576.00	200.00	56.00	18.00	0.
45	PCT BASE REPAIR	38.87	100.00	100.00	100.00	78.81	83.21	11.11	0.	28.57	100.00	0.
46	PCT DEPOT REPAIR	61.13	0.	0.	0.	21.19	16.79	88.89	100.00	71.43	0.	0.
47	AVERAGE BASE REPAIR CYCLE	.17	1.14	2.21	.23	.07	.07	0.	0.	0.	.06	0.
48	PCT ACTIVE REPAIR	67.61	100.00	99.91	37.77	98.47	99.18	0.	0.	0.	100.00	0.
49	PCT WHITE SPACE	32.39	0.	.09	62.23	1.53	.82	0.	0.	0.	0.00	0.
50	NO. OF ITEMS IN REPAIR (EOP)	102.00	2.00	1.00	1.00	58.00	40.00	0.	0.	0.	0.	0.
51	NO. OF ITEMS BACKLOGGED (EOP)	3.00	0.	0.	3.00	0.	0.	0.	0.	0.	0.	0.

	S U P P L Y	TOTAL	PMPH1	PMPH2	RDASY	RDC11	RDC12	BM500	SMTBM	MISLS	CAMRA	OTHER
54	TOP DOLLAR INVEST.(1000)(EOP)	204078.40	.30	.60	6.00	34.00	18.50	9999.00	1.80E05	13986.00	52.00	0.
55	FILL RATE PERCENT	85.42	100.00	100.00	67.18	85.59	9.16	100.00	100.00	100.00	100.00	0.
56	NUMBER OF BACKORDER-DAYS	29.49	0.	0.	3.11	5.25	21.12	0.	0.	0.	0.	0.
57	NUMBER OF UNITS DEMANDED	1372.00	4.00	11.00	195.00	118.00	131.00	608.00	200.00	86.00	17.00	0.
58	PCT OFF-THE-SHELF	85.42	100.00	100.00	67.18	85.59	9.16	100.00	100.00	100.00	100.00	0.
59	PCT EXPEDITED REPAIR	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
60	PCT PREEMPTION	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
61	PCT DEMANDS NOT SATIS.	14.58	0.	0.	32.82	14.41	90.84	0.	0.	0.	0.	0.
62	NUMBER OF CANNIBALIZATIONS	2.00	0.	0.	2.00	0.	0.	0.	0.	0.	0.	0.
63	NO. ITEMS ON BACKORDER (EOP)	3.00	0.	0.	0.	0.	3.00	0.	0.	0.	0.	0.

	E Q U I P M E N T	TOTAL	TRUCK	OTHER
68	TOP DOLLAR INVEST.(1000)(EOP)	12.00	12.00	0.
69	EQUIPMENT HOURS AUTH. (100)	4.80	4.80	0.
70	EQUIPMENT HOURS AVAIL. (100)	4.80	4.80	0.
71	PCT USED-UNSCHED MAINT	8.55	8.55	0.
72	PCT USED-SCHED MAINT	0.	0.	0.
73	PCT UNUSED	91.45	91.45	0.
74	NUMBER OF BACKORDER-DAYS	.02	.02	0.
75	NUMBER OF UNITS DEMANDED	220.00	220.00	0.
76	PCT AVAILABLE	97.27	97.27	0.
77	PCT PROV. BY EXPEDITE	.91	.91	0.
78	PCT PROV. BY PREEMPTION	0.	0.	0.
79	PCT DEMANDS NOT SATIS.	1.82	1.82	0.
80	EQUIP HOURS BACKLOG(1000)(EOP)	0.	0.	0.

Figure 13. Main module performance summary report (Level 1) - S.P. 4.0 (Concluded)

simulation run. In the LCOM simulation, a hit matrix indicates the number of times a task was hit, i.e., done. These reports are primarily used as debugging tools.

As previously stressed, the post processor data file had to be requested when running the Main Model. Of primary use for evaluating or constraining the LCOM run are the Manpower Matrix, Parts Post Processor, and SE Post Processor. The Graph, Display, and Mission are summary reports used mainly as debugging tools.

Figure 14 shows the productive utilization matrix for crew chiefs (CREWCH). On the Y axis is the number of CREWCHs needed simultaneously during the (X axis) 1/2 hour periods throughout the day. The numbers of the matrix indicate the number of times that crewsize was needed during the simulation period. Figure 15 shows the On-Equipment Back-Order Matrix for the CREWCH. This indicates when work was delayed because not enough CREWCHs were available.

After arriving at a steady-state unconstrained run, the LCOM user then works with the Personnel, Supply, and Support Equipment outputs of the PSR to determine crewsize and spare parts levels. These levels are targeted toward a desired sortie rate and supply rate as defined in the scenario. A new Main Module Simulation run is made with the above constraints. Through this iterative process, the user is systematically striving to determine, what levels of crew size per shift per Air Force Specialty Code (AFSC) and of spare parts stock properly constrain the maintenance function in order to attain the predefined scenario sortie rate and supply effectiveness. Refer to Figure 12 for data flow.

Figure 16a shows the <u>Modeled</u> while Figure 16b shows the <u>Actual</u> Support Equipment Graph. This post processor attempts to differentiate between the number of times SE is required for tasks modeled separately in LCOM, and the real world situation where maintenance crews sometimes share the same SE on two or more simultaneous jobs.

Examination of the various Main Module output reports and the Post Processor Report affords the experienced LCOM user a wealth of information about the simulation process. As LCOM users become more and more familiar with the various reports, they find more uses for them than briefly sketched in this short description. See Reference 1 for more specific information about the entire LCOM process.

IV. SUMMARY AND CONCLUSIONS

Table 1 summarizes the comparison of R&M, LCOM, and EVM. Both the R&M and EVM are average value models which produce expected value results. Figure 4 shows that while the R&M and EVM use only the maintenance environment network data, LCOM uses the maintenance environment network plus the operations scenario to simulate the attempt of a weapon system to meet a flight and environment scenario. It uses operations scenario data to drive the

PRODUCTIVE UTILIZATION MATRIX FOR RESOURCE CREWC (2)

```
                                                                                                   10
10          1                                                                                       *
 *          3 2              *                                                  *                   *
 *          7 2              *                          3                       *                   *
 *         12 6              *                          3 2                     *                   *
 *          514            2 *                    2 9 1211  2 1                                      5
5           8 3           15 1                    817 1111  7 2    1             *                  *
 *            6     2615  10 5* 4                 12 9  7 7 11 5   7 2           *                  *
 *            3      813  911* 9 1                                               *          1       36 1818    *
 *                   2 8  10*15 1  1          6   7      5 1116 12 8   4        *   3330 2215 2618 18 9  2     *
 *               3236       9* 816 12         14  5 1      510 1312 12 8*           3 6 1421  918 1827 34 0 1818 3636
  3636 3636 3636 0 0 3636  4 0  0 0  0 0 018 2336 3616 2 0  0 0  0 2  314 2028 3636
+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+
0    1    2    3    4    5    6    7    8    9    10   11   12   13   14   15   16   17   18   19   20   21   22   23   0
```

ON EQUIPMENT PRIME RESOURCE SUMMARY

TOTAL MANHOURS	778.76	TASKS COMPLETED	1462
AVE MANHRS/DAY	21.63	MAX CREW SIZE	1
ST DEV MNHRS/DAY	2.24	TIMES MAX CREW REQ	1462
TASK SEG PROC	1462	MEAN CREW SIZE	1.00
AVE SEGMENT TIME	.53	ST DEV CREW SIZE	0.
ST DEV SEG TIME	.53	TW AVE CREW SIZE	1.00

ON EQUIPMENT SUBSTITUTE RESOURCE SUMMARY

TOTAL MANHOURS	0.	TASKS COMPLETED	0
AVE MNHRS/DAY	0.	MAX CREW SIZE	0
ST DEV MNHRS/DAY	0.	TIMES MAX CREW REQ	0
TASK SEG PROC	0	MEAN CREW SIZE	0.
AVE SEGMENT TIME	0.	ST DEV CREW SIZE	0.
ST DEV SEG TIME	0.	TW AVE CREW SIZE	0.

OFF EQUIPMENT PRIME RESOURCE SUMMARY

TOTAL MANHOURS	0.	TASKS COMPLETED	0
AVE MNHRS/DAY	0.	MAX CREW SIZE	0
ST DEV MNHRS/DAY	0.	TIMES MAX CREW REQ	0
TASK SEG PROC	0	MEAN CREW SIZE	0.
AVE SEGMENT TIME	0.	ST DEV CREW SIZE	0.
ST DEV SEG TIME	0.	TW AVE CREW SIZE	0.

OFF EQUIPMENT SUBSTITUTE RESOURCE SUMMARY

TOTAL MANHOURS	0.	TASKS COMPLETED	0
AVE MNHRS/DAY	0.	MAX CREW SIZE	0
ST DEV MNHRS/DAY	0.	TIMES MAX CREW REQ	0
TASK SEG PROC	0	MEAN CREW SIZE	0.
AVE SEGMENT TIME	0.	ST DEV CREW SIZE	0.
ST DEV SEG TIME	0.	TQ AVE CREW SIZE	0.

SHIFT SUMMARY

SHIFT NUMBER	1	2	3
START - STOP HOURS	0 - 8	8 - 16	16 - 0
ON EQUIP MNHRS PRIME	340.83	327.91	110.01
ON EQUIP MNHRS SUB	0.	0.	0.
OFF EQUIP MNHRS PRIME	0.	0.	0.
OFF EQUIP MNHRS SUB	0.	0.	0.
MAX CREW REQUIRED	1	1	1
LCOM SPACES (25% IND)	1.58	1.52	.51

50 DAYS OF SIMULATION * 36 DAYS OF DATA * FIRST COMPLETE 5 DAY BLOCK STARTS DAY 14 REPEATS EVERY 7 DAYS

Figure 14. S.P. 4.0's Manpower matrix (HIS).

```
                              ON EQUIPMENT BACK-ORDER MATRICES FOR RESOURCE CREWC (  2)
 PRIME RESOURCE REQUIREMENTS IN EXCESS OF ONHAND BALANCE
*                1                                                                                          
*                1                     *                                       *                                       *
*                3                     *                                       *                                       *
*                2                     *                                       *                                       *
  1414 1414 1414  714 1414 1414 1414 1414 1414 1414 1414    1  2 2    1       1  2 *                                       *
                                                         1314 1212 1314 1413 1214 1414 1414 1414 1414 1414 1414 1414 1414
+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+
0    1    2    3    4    5    6    7    8    9    10   11   12   13   14   15   16   17   18   19   20   21   22   23   0
 TASKS IN BACKORDER WITH CREWC AS A PRIME RESOURCE
*                1                     *
*                1                     *                                       *                                       *
*                5                     *                                       *                                       *
*                4                     *                                       *                                       *
  1414 1414 1414  314 1414 1414 1414 1414 1414 1414 1414    1  2 2    1       1  2 *     1                                 *
                                                         1314 1212 1314 1413 1214 1414 1314 1414 1414 1414 1414 1414 1414
+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+
0    1    2    3    4    5    6    7    8    9    10   11   12   13   14   15   16   17   18   19   20   21   22   23   0
 TASKS IN BACKORDER WITH CREWC AS A SUBSTITUTE RESOURCE
*                1                     *
*                                      *                                       *                                       *
*                4                     *                                       *                                       *
*  3 2  2 1      2                     *    1  1 2   1      1  2 2  2 1        1 *  2  3                                   *
  1112 1213 1414  714 1414 1414 1414 1414 *  1  3 1  3 2  5 7  4 4  1 2  1 3  1 2* 3 1  1 1  1 1                          *
                                       1412 1011 1012  9 6  8 8 1111 1311 1212 1111 1013 1313 1414 1414 1414 1414 1414
+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+
0    1    2    3    4    5    6    7    8    9    10   11   12   13   14   15   16   17   18   19   20   21   22   23   0

PRIME RESOURCE BACKORDER SUMMARY                                        SUBSTITUTE RESOURCE BACKORDER SUMMARY

 TL BACKORDER EVENTS     30    AVE B/O DURATION    .10                   TL BACKORDER EVENTS      71
 AVE CREW REQUESTED    1.00    STD DEV B/O DUR     .09                   AVE B/O DURATION        .29
 MAX CREW REQUESTED       1    MAX B/O DURATION    .53                   AVE TASKS IN B/O        .06
 AVE TASKS IN B/O       .01                                              MAX B/O DURATION       1.12
 AVE MEN IN B/O         .01    TL MNHRS B/O       2.39                   ST DEV B/O DURATION     .30

SHIFT SUMMARY

 SHIFT NUMBER              1          2          3
 START - STOP HOURS     0 - 8      8 - 16     16 - 0
 AVE TASKS PRIME B/O      .02        .01        .00
 AVE MEN PRIME B/O        .01        .01       0.
 TL MNHRS PRIME B/O      1.48        .92       0.
 AVE TASKS SUB B/O        .03        .12        .03

     50 DAYS OF SIMULATION  *  14 DAYS OF DATA  *  FIRST COMPLETE 2 DAY BLOCK STARTS DAY 12 REPEATS EVERY 7 DAYS
```

Figure 15. Matrix post processor sample backorder output.

```
                          MODEL SUPPORT EQUIPMENTS DEMANDS

                          RESOURCE ID     10     ON-EQUIPMENT

4+                                                      1  1 1                         1                    +4
3+                                                      1  2 7               4  4 3  4                      +3
2+                         2  1 4  1 1  3 4  3 4  7 2526 10 3  5 4  1 1  2 2 1118 1419 1419 11 2             +2
1+ 2216  515 2510  3     1  2 3 1321 3520 1112 1129 3626 3927 2621 3018 1942 2917 1316 2832 2932 2934 3215  413 1915  815 +1
0+ 3844 5545 3550 5760 6059 5857 4737 2436 4847 4627 2130 2124  6 5 2039 3614 3042 4542 21 6 1315 13 6 1743 5647 4145 5245 +0
+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+++
     1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20   21   22   23   24

TOTAL DEMANDS             1269      AVERAGE DEMANDS PER HOUR       .881      AVERAGE QUANTITY REQUESTED    1.00
TOTAL EQUIPMENT HOURS   209.48      AVERAGE TASK SEGMENT DURATION  .007      MAXIMUM QUANTITY REQUESTED       1
PERCENT OF TIME IN USE     .15
```

Figure 16a.

```
                          ACTUAL SUPPORT EQUIPMENT DEMANDS

                          RESOURCE ID     10     ON-EQUIPMENT

4+                                                         1                                                +4
3+                                                     2  3 7                4  4 3  4 1                    +3
2+                              1    3  1 1  3 3  2 4  7 2425  9 3  5 4  1   1 2 1018 14 8 1319 11 1        +2
1+ 2216  515 2510  3     1  2 3 1322 3621 1112 1130 3726 3927 2722 3118 1942 2918 1416 2932 2934 3034 3216  413 1915  815 +1
0+ 3844 5545 3550 5760 6059 5857 4737 2436 4847 4627 2130 2124  6 5 2039 3614 3042 4542 21 6 1315 13 6 1743 5647 4145 5245 +0
+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+----+++
     1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20   21   22   23   24

TOTAL DEMANDS             1251      AVERAGE DEMANDS PER HOUR       .869      AVERAGE QUANTITY REQUESTED    1.00
TOTAL EQUIPMENT HOURS   208.33
PERCENT OF TIME IN USE     .14
```

Figure 16b. S.P. 4.0's Support equipment model and actual matrices -- on-equipment demands (HIS).

Table 1. Comparison of R&M, LCOM and EVM

	INPUT DATA COMPATIBLE	PREPROCESSOR	ADDITIONAL DATA OR FORMS	PROCESSING	OUTPUT
R&M	Extended Form 11 with optional title FH/SORTIE ratio and 0 CR file-Maintenance Environment Network Data	≠ Transformation and then KONVERT to R&M Forms.	Ø CR (Cross Reference) file	Sets up a hit matrix per fixed network structure and computes average resource values per task as related to shop action.	MTTR by task per LRU. MTTR as % of Σ. MMH as % of Σ. MMH/KFH MTTR/KFH No Spares Info.
LCOM	Extended Form 11 with SPEC card-Maintenance Environment Network Data	PHASE I & II programs generate LCOM Forms 10, 11 12, 13, 14, 15*, 16, and 18	LCOM Forms 10-03 15*, 17, 20, 21, 22, and 23-Operations Scenario	LCOM plus the data logic simulates the attempt of a WS to meet a flight & environment scenario by having this "scenario drive the maintenance and resource network"	Main Model - Performance Summary Report Post Processor Manpower, Matrix, Mission, Parts Graph, Display, & SE Reports.
EVM	Extended Form 11 with required parameter card and call section list Maintenance Environment Network Data	EVMP1 - part of EVM - expands the Ext. F. 11 data but keeps the same structure	None, if the frequency adjustments are on the original Extended Form 11 header cards.	EVMP2 - uses the flight line network to control the use of Phase Inspection and Unscheduled maintenance to compute average resource #'s	Per Network section - ON & OFF EQUIP requirements of AFSCs, SE, spares with summary. Line printer plot.

Ø Can be input by user either place.
Weight and QPA needed by RMCM, but not by R&M.

≠ Manual transformation may be very difficult.
KONVERT not updated to RMCM, and the test versions of R&M.

*Can be input by user either place.

maintenance environment network. All three models deal with logistics requirements--manpower, spare parts, and support equipment.

Volume II of this technical paper gives annotated examples and results of the equivalence testing for the two average value models, R&M and EVM. Suggestions are made for improvements which could be made for the average value models.

This concluding paragraph speaks directly to Question 3 of this study--How can the models best be used in the weapon systems acquisition process (WSAP)?

LCOM can be used across levels of detail in early phases of the WSAP to compare the impact of alternative maintenance and deployment concepts. LCOM is the only model of the three which can show impacts of the design, support resources, and concepts on sortie generation/readiness capability. However, many design trade-offs do not require a full assessment of readiness impact. They may be at a detailed level which would be "lost in the noise" of a full system analysis, but individually contribute to reduce support costs and improve availability. Similarly, "first cut" looks at a variety of design options can be based on reliability and manhours. The full system impact need be assessed only for the final decision. The EVM and R&M models are designed to provide quick turnaround answers to isolate details, design differences, and exploratory trade-offs.

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